VII. A PROPOSAL

FOR ADJUSTING A NEW SCALE TO THE MERCURIAL THERMOMETER;

Inclosed in a letter, addressed to the late Rev. President Willard, dated August, 1789.

By EDWARD A. HOLYOKE, M. D. A. A. S.

IT is matter of much regret, that an instrument so useful, so subservient to the purposes of philosophy, medicine, economy, and the arts, and which is so frequently employed, as the Thermometer, should not hitherto have been furnished with a more natural, useful, and commodious Scale; as there is not any one in common use, that has fallen under my observation, that is not liable to great objections, or which has been formed upon such natural and philosophical principles, as might be wished, or as indeed might have been expected, considering the many able hands it continually passes through. These considerations led me to the following reflections, and must apologize for their communication.

Fluids are the most convenient substances for forming Thermometers; all solids being found very inconvenient and unmanageable for common use. Now all fluids, fit for the purpose of a Thermometer, are liable, by great degrees of cold, to be congealed, and so converted into solids; and can never therefore be a proper measure of any degree of cold greater, than what will just reduce them to a solid state. On the other hand, all such fluids are liable, by a certain degree of heat, to be made to boil; after or beyond which point they dilate in an irregular and desultory manner, and cannot by any increase of heat be made to expand much farther; but, instead of expanding, are

converted into vapour; and if the vessel or tube, in which they are contained, be small and closed, as for thermometers they must be, they are subject to be burst; or, if left open, the fluid by evaporation is dissipated and lost. So that beyond this boiling point no fluid can be a measure of heat. Hence nature seems to have limited, in the most rigorous manner, the degrees of heat, which each individual fluid is capable of measuring, when formed into a thermometer.

These being undoubted facts, it follows, that the most natural point, at which to fix the zero, is precisely that, at which the fluid employed just begins to lose its fluidity, and to put on the form of a solid. And the most natural point, at which to terminate the scale, is that, at which it just begins to boil, or at which it ceases to be a measure.

This appears so obvious at first glance, that we may naturally suppose it would occur to every one engaged in constructing a new scale. But unhappily the fact, that mercury, the fluid best adapted to thermometrical purposes, was capable of congelation, was unknown at the time, that Messrs. Fahrenheit and Reaumur adjusted their scales to the thermometer; otherwise it is probable they would have proceeded upon a very different plan. These two scales have been for some time and still are the most approved and employed in Europe; the former in England and the more northern parts, and the latter in France and perhaps the more southern. These are therefore, I suppose, as little liable to objections, as any. But they both fall much short of that perfection, which it were to be wished so useful an instrument were possessed of; or as the present improved state of philosophy and philosophical instruments seems to demand.

Fahrenheit begins his scale in the most arbitrary manner, and unluckily has pitched upon a point by much too high; so that whenever the cold is so great as to reduce the mercury below 0 on his scale, which happens every winter with us in North America, there is a necessity

of prefixing the negative sign in our meteorological observations ; of which there would not be the least occasion, if the scale were properly adjusted.

Reaumur has placed the zero of his scale at the point, at which water just begins to freeze ; which is equal to 32° of Fahrenheit's scale. This appears more natural and philosophical indeed than Fahrenheit's ; because the point, at which water freezes, is a fixed point, and easily and certainly determinable ; but is at the same time much more inconvenient than his, as it is necessary to affix the sign + or — to every degree noted down ; which is not only troublesome in itself, but is a constant source of error. For if the sign happen to be omitted, when the degree to be noted is within a few, either above or below zero, the notation is quite uncertain, and the error *may* be great. But if the wrong sign be prefixed, it *must* be great. Nor is this all ; the degrees on Reaumur's scale, which are each equal to $2\frac{1}{4}$ of Fahrenheit's, are by much too large. Too large even for the common routine of meteorological observations, which are far from requiring the greatest degree of accuracy. It would certainly be thought too vague an expression to say, e. gr. + 15, or —16°, when the mercury stands by the scale in the interval between those two degrees. And if the expression were conveyed in fractions (which is still increasing the trouble), the parts of a degree must be estimated by the eye, which seems too inaccurate a mode of determining ; especially when more precision may be obtained by an easier one.

Of these two thermometers then, there cannot be any hesitation, with us at least in this country, which to prefer ; Reaumur's being so very incommodious for the reasons just mentioned. But Fahrenheit's, though more convenient, is certainly imperfect and needs alteration.

I am fully sensible of the great inconvenience there is in introducing a new standard. So many observations have been made on

the old thermometers, and published to the world, not only by individuals, but by all the literary societies in Europe ; and the mind of the public is so inured to the scales hitherto in use, that it may perhaps be impossible that an alteration should ever obtain, and come into general use. But as far as the considerations of greater ease and convenience, more precision, and a diminution of the sources of error, will justify an alteration ; so far we have reason for making the proposal. The following is suggested for the consideration of the learned, as a remedy for the above mentioned defects.

Let a thermometrical tube of a sufficient length, whose bore is perfectly true and equable throughout, be properly filled with quicksilver and hermetically sealed. Let this thermometer be placed, in extremely cold weather, in a frigorific mixture, so as to congeal the fluid ; and let the point, at which the quicksilver just begins to freeze, be carefully marked upon the glass tube with a diamond. Let this be the beginning of the scale, and let 0 be marked upon it accordingly. (See fig. 10.) Then let the thermometer be removed into fair water, and let the point, to which the mercury rises in the tube, when the water just begins to freeze, be marked upon the tube. Now as the points, at which the mercury rises in these two cases respectively, are certainly and invariably determinable, and the distance between the freezing point of mercury and the freezing point of water, seems to be a natural and convenient measure, by which to adjust all the other divisions of the scale ; I would propose, that the freezing point of water be marked on the scale 100, and the space between 0 and 100 be divided into so many equal parts or degrees. Or if it be impracticable and inconvenient to freeze the mercury so as to determine the point 0 in that way, the scale may be adjusted, by first finding the freezing point of water, and marking that 100, and then applying heat to the same water till it boils, and marking the boiling point 350 ; then let the interval be-

tween 100 and 350 be divided into 250 equal parts or degrees; and let 100 of those degrees be set off downwards from the freezing point, marked 100 on the scale; and let that point be marked 0, which will be as determinate and as exact, as if the same point were adjusted from the actual freezing of mercury; provided the tube be of an exactly equable bore throughout, and that mercury freezes at exactly 40° below 0, by Fahrenheit's scale; which by the experiments made at Hudson's Bay and reported in the *philosophical transactions*, seems to be the truth, or at furthest within one degree of it. Having thus found the two points, at which mercury and water freeze, and divided the interval into one hundred degrees, let the scale then be continued on, in divisions of the same extent, till we arrive at the point, at which quicksilver boils. This point is said to be 656 by Fahrenheit's scale, which is equal by our new scale to 962,5. Here then the scale must terminate, as at this point mercury loses its thermometrical capacity.

One hundred degrees of the proposed scale will then be just equal to 72 degrees of Fahrenheit, and equal to 32 degrees of Reaumur's scale in extent.

The more noted points of the Thermometer will then stand as follows, in the three different scales.

	New scale.	Fahrenheit.	Reaumur.
Quicksilver freezes at - - -	0	— 40	— 32
Fahrenheit's scale begins - -	55,55	0	— 14,2
Water freezes, and Reaumur's scale begins	100	+ 32	0
Blood heat - - - -	191,66	+ 98	+ 29,34
Spirit of wine boils - - -	291,7	+ 170	+ 61,28
Water boils - - - -	350	+ 212	+ 80
Melted Tin fixes - - -	666,66	+ 442	+ 182,22
Melted Lead fixes - - -	904,54	+ 612	+ 257,77
Quicksilver and linseed oil boil -	962,5	+ 656	+ 277,33

A scale thus adjusted to a mercurial Thermometer is capable of measuring every degree of heat, of which mercury can be a measure. The divisions appear natural, and the degrees are so minute as

never, but on such occasions as require very great accuracy, to need any subdivision, or the use of fractional parts. The notation will be as simple and convenient, as the nature of things will admit, and always direct and affirmative; and cannot in any case call for the use of either the negative or positive sign; and is therefore less apt to lead into any error. So that it is hoped the proposed scale is free from all the objections, to which those now in use are liable, and is more natural and philosophical.

To reduce a given degree of Fahrenheit's scale to its corresponding degree in the proposed scale,

Add 40 to the given degree, multiply that sum by 100, and divide the product by 72. The quotient will be the corresponding degree by our scale, if the given degree of Fahrenheit be above 0. But if the given degree be below 0, or have the negative sign, then subtract the given degree from 40, and proceed as above.

To reduce a given degree of the proposed scale to its corresponding degree of Fahrenheit,

Multiply the given degree by 72, divide the product by 100, and subtract 40 from the quotient, the remainder is the degree of Fahrenheit sought, to which the positive sign must be prefixed. But if the quotient be less than 40, then subtract it from 40, the remainder is the degree in whole numbers; but if there be a fraction remaining in the division, *that* must be subtracted from the quotient, and the remainder will be correctly, the degree sought; to which the negative sign must be prefixed.

But the readiest and most convenient mode of comparing any two or more thermometers is by a juxtaposition of their scales.*

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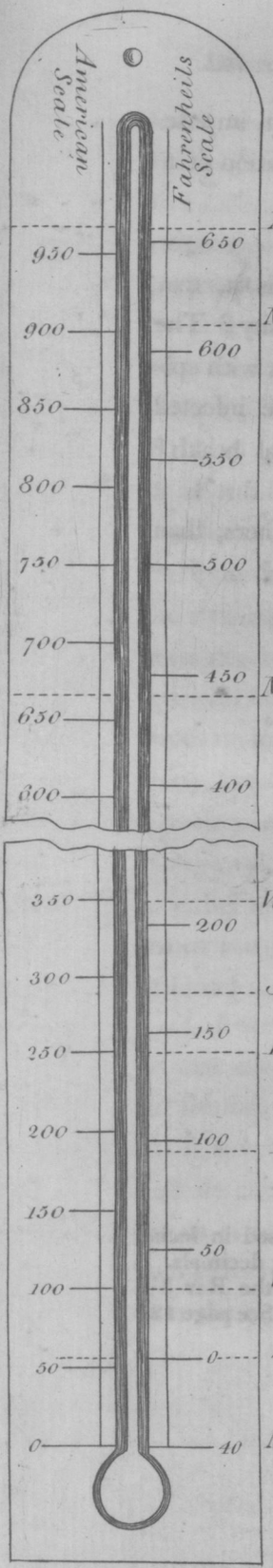
* The writer, having recently revised this communication, has made some small corrections, authorized by late discoveries.

Fig. 10.



	American Scale	Fahrenheits Scale	Reaumurs Scale
Mercury boils	966,66	656	+277,33
Melted Lead fixes	905,55	612	+257,77
Melted Tin fixes	669,44	442	+182,22
Water boils	350	212	+ 80
Sp.t of Wine boils	291,66	170	+61,28
Bees-wax melts	252,77	142	+48,89
Blood heat	191,66	98	+29,34
Water freezes	100	32	0
Zero of Fahrenheit	55,55	0	—14,2
Mercury freezes	0	—40	—32

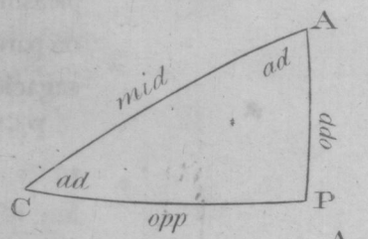


Fig. 1.

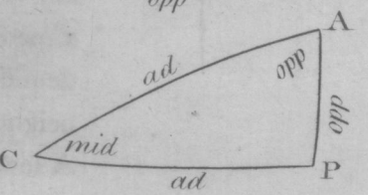


Fig. 2.

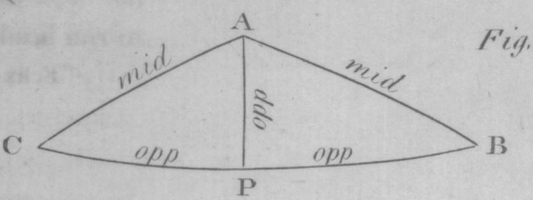


Fig. 3.

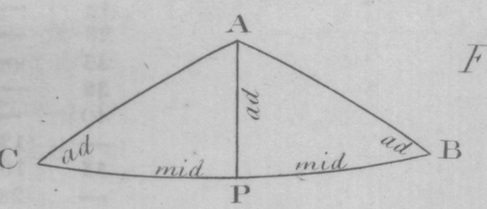


Fig. 4.

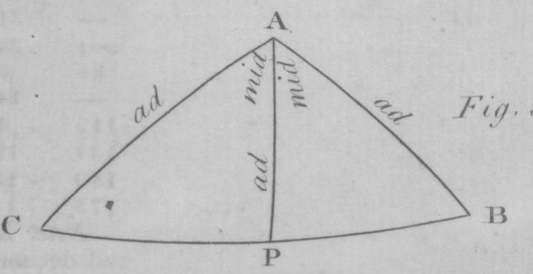


Fig. 5

Wightman Sc.